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Biological and mechanical complications of angulated abutments connected to fixed dental prostheses: A systematic review with meta-analysis

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Abstract: OBJECTIVES To evaluate the biological and mechanical complications of angulated abutments on full-arch and partial jaw rehabilitations with a follow-up for at least 1 year. METHODS Electronic search was carried out in MEDLINE, EMBASE and Web of Science. Studies published between January 2000 and January 2019 were included. The quality of the included studies was assessed. The data extraction was focused on implant loss, marginal bone loss and mechanical complications, and meta-analyses were performed for marginal bone loss, mechanical complications and implant failure. RESULTS Nine studies, three prospective and six retrospective cohort studies were included. They reported on 797 patients that received 4127 implants. The total number of abutments was 4079 of which 1673 were angulated, and 2406 were straight. All abutments were prefabricated. Angulated abutments were associated with increased implant failure rates (two studies; RR = 7.30; 95% CI = 2.79-19.08) and an effect that was both statistically significant ($P < .001$) and clinically relevant. Three studies reported differentiated data for mechanical and technical complications at 1 year of follow-up, being mostly related to the retention screw while screw fracture. Angulated abutments were associated with a statistically significant increase in MBL 1 year after insertion compared to straight abutments (three studies; MD = 0.08 mm; 95% CI = 0.01-0.14 mm; P = .02), which might be, however, clinically negligible. CONCLUSIONS The prosthetic complications such as screw loosening and abutment loosening were frequent. After 1 year of follow-up, implants supporting angulated abutments yielded significantly more marginal bone loss than those supporting straight abutments.

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Biological and mechanical complications of angulated abutments connected to fixed dental prostheses. A systematic review with meta-analysis.

Yuki Omori[1,2] | Niklaus P. Lang[3] | Daniele Botticelli[2,4] | Spyridon N. Papageorgiou[5] | Shunsuke Baba[1]

[1]Department of Oral Implantology, Osaka Dental University, Osaka, Japan

[2]ARDEC Academy, Ariminum Odontologica, Rimini, Italy.

[3]School of Dental Medicine, University of Berne, Berne, Switzerland

[4]DentalPro Academy, Milan, Italy

[5]Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, Zurich, Switzerland

Running head: Angulated versus straight implant abutments

Key words: Prosthetic dentistry, fixed dental prosthesis, FDPs, complications, implant dentistry, axial load, non-axial load, systematic review

Corresponding author: Daniele Botticelli, ARDEC Academy, by Ariminum Odontologica, Viale Giovanni Pascoli 67 – 47923 RIMINI (ITALY); E-mail: daniele.botticelli@gmail.com; Tel.-Fax: +39 0541 393444.

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ORCID

Yuki Omori: https://orcid.org/0000-0001-6147-8903

Niklaus P. Lang: https://orcid.org/0000-0002-6938-9611

Daniele Botticelli: https://orcid.org/0000-0003-2804-1632

Spyridon N. Papageorgiou: https://orcid.org/0000-0003-1968-3326

Shunsuke Baba:

ABSTRACT

Objectives: To evaluate the biological and mechanical complications of angulated abutments on full-arch and partial jaw rehabilitations with a follow up for at least 1 year.

Methods: Electronic search was carried out in MEDLINE, Embase, and Web of Science. Studies published between January 2000 and January 2019 were included. The quality of the included studies was assessed. The data extraction was focused on implant loss, marginal bone loss and mechanical complications and meta-analyses were performed for marginal bone loss, mechanical complications, and implant failure.

Results*:* Nine studies, three prospective and six retrospective cohort studies were included. They reported on 797 patients that received 4127 implants. The total number of abutments were 4079 of which 1673 were angulated, and 2406 were straight. All abutments were prefabricated.

Angulated abutments were associated with increased implant failure rates (2 studies; RR=7.30; 95% CI=2.79 to 19.08) and an effect that was both statistically significant (P <0.001) and clinically relevant. Three studies reported differentiated data for mechanical and technical complications at 1 year of follow-up, being mostly related to the retention screw while screw fracture. Angulated abutments were associated with a statistically significant increase in MBL 1 year after insertion compared to straight abutments (3 studies; MD=0.08 mm; 95% CI=0.01 to 0.14 mm; P=0.02), which might be however clinically negligible.

Conclusions: The prosthetic complications such as screw loosening and abutment loosening were frequent. After one year of follow-up, implants supporting angulated abutments yielded significantly more marginal bone loss than those supporting straight abutments.

1 | INTRODUCTION

Implant supported restorations have been shown to be a reliable way to rehabilitate partially or completely edentulous areas, with high survival rates in the long term reported by systematic reviews of clinical evidence.[1,2]

As far as implant inclination is concerned, straight implants are usually preferred in order to facilitate simple and esthetic rehabilitation. However, axial implant placement is often not feasible due to anatomical limitations pertaining to resorbed alveolar ridges or compromised alveolar crest geometry.[5-10] In such cases, tilted implant placement might be indicated like the all-on-four reconstruction protocol, in which the two posterior implants are deliberately placed in a distal direction to increase the implant-to-bone surface.

Evidence from a biomechanical investigation employing photo-elastic stress analysis indicates that implants should be placed in an axial direction, since tilted implant placement seems to be associated with higher stress distribution.[3] However, this notion could not be confirmed by a recent systematic review with meta-anaysis.[4] That review assessed implant failure, marginal bone loss (MBL), and other biological or technical complications of prosthetic restorations supported by tilted implants. Based on the seventeen non-randomized studies, it was concluded that tilted implants had similar outcomes in terms of implant survival and peri-implant bone loss compared to straight implants after at least 3 years in function.

However, in the case of tilted implants, it is not only the implant per se that is placed in a non-axial direction, but also the prosthetic abutment that needs often to be placed tilted to facilitate a better emergence profile and enable prosthetic rehabilitation. Various systematic reviews have evaluated several aspects related to abutment connection, and abutment material including its height.[11-14] However, no systematic reviews have been published comparing the outcomes of straight and angulated abutment installation.

Hence, the aim of the present review was to evaluate the biological and mechanical complications of angulated abutments on full-arch and partial jaw rehabilitations with a follow up for at least 1 year.

2 | MATERIAL AND METHODS

2.1 | Protocol and registration

The review followed the guidelines reported in the Cochrane Handbook[15] and in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[16] while its protocol was registered in PROSPERO (registration number CRD42019126477).

2.2 | Focused question

Which are the biological and mechanical complications of angulated abutments connected to fixed dental prostheses?

The following focus question is proposed according to the PICO format (Stone PW 2002)[17]

In patients with fully or partially edentulous conditions rehabilitated with fixed implant-supported prosthesis (P), which are the implant failure rate and the incidence of the biological (marginal bone loss) and mechanical (prosthetic) complications (O) of the angulated abutments (I) compared to those straight (C)?

2.3 Eligibility criteria

The Participants-Intervention-Comparison-Outcome-Study design (PICOS) structure for this review was as follows:

- Population: partial or fully edentulous adult patients
- Intervention: angulated abutments connected to fixed dental prostheses (FDPs)
- Comparison: straight abutments connected to FDPs
- Outcome: biologic and mechanical complications after at least 1 year of follow-up
- Study design: randomized or non-randomized comparative clinical studies in humans, prospective and retrospective clinical studies.

The inclusion criteria in detail included randomized and non-randomized clinical studies with a minimum mean follow-up of 1 year and articles only written in English. Excluded were studies not related to topic, published before 2000, not in English, pre-clinical or non-clinical studies or technical description or literature review, and studies with less than 20 patients. Moreover, studies related to abutments with angulated screw channels were also excluded.

2.4 | Information sources and searches

An electronic search was carried out by two reviewers (DB and KAAA) in Medline® (via PubMed), Embase®, and Web of Science® for studies published in English between January 2000 - January 2019 (Appendix S1). MeSH (Medical Subject Headings), EMTREE, and 'free-text' terms were adopted and combined using appropriate Boolean operators. Moreover, the System for Information on Grey Literature in Europe (SIGLE) database was browsed through http://www.opengrey.eu. An additional manual search was performed in duplicate (DB and KAAA) since 2015 in the following journals: Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, the international Journal of Oral and Maxillofacial implants, Implant Dentistry, Journal of Oral Implantology, Journal of Oral Rehabilitation, The International Journal of Periodontics and Restorative Dentistry, The International Journal of Prosthodontics, The Journal of Prosthetic Dentistry.

Electronic Search strategy performed in Medline® (via PubMed):

Search ((((((((("Mouth, Edentulous"[Mesh]) OR "Jaw, Edentulous"[Mesh]) OR "Jaw, Edentulous, Partially"[Mesh]) OR "Alveolar Bone Loss"[Mesh])) OR (((((((((((((((edentulous maxilla) OR partial edentulism) OR partial edentulous jaws) OR fully edentulous jaws) OR edentulous jaws) OR edentulous mandible) OR edentulous patients) OR atrophic maxilla) OR atrophy maxilla) OR atrophied maxilla) OR atrophied mandible) OR atrophic jaws) OR total edentulous) OR partially edentulous) OR complete edentulism))) OR ((((("Denture Design"[Mesh]) OR "Denture, Partial, Fixed"[Mesh]) OR "Dental Prosthesis Design"[Mesh])) OR ((((((((((((((((((((((((((((((((((((("Dental Prosthesis, Implant-Supported"[Mesh]) OR full arch implant supported) OR full arch fixed prosthesis) OR full-arch fixed prosthesis) OR full-arch implant supported fixed prosthesis) OR dental implant prosthesis) OR fixed implant prosthodontics) OR hybrid implant prostheses) OR implant prosthesis) OR implant supported fixed prosthesis) OR implant supported fixed prostheses) OR fixed implant prostheses) OR implant prostheses) OR implant-supported fixed dental prostheses) OR implant-supported restoration) OR implant-supported fixed partial dentures) OR maxillary implant supported prosthesis) OR dental implant rehabilitation) OR screw retained prosthesis) OR fixed implant prosthesis) OR all-on-four) OR all-on-4) OR all on four) OR all on 4) OR all-on-six) OR all-on-6) OR all on six) OR all on 6) OR all on 4 dental implants) OR all-on-four) OR all on four dental implants) OR all-on-six dental implants) OR all-on-6 dental implants) OR all on six dental implants) OR all on 6 dental implants) OR fixed restoration) OR fixed prosthodontics) OR implant supported) OR fixed partial dentures) OR fixed dental prosthesis) OR fixed dental prostheses))) AND ((((((((((((((((tilted implant) OR angulated implant) OR angled implant) OR inclined implant) OR offset implant) OR non axial implant) OR non axially implant) OR non parallel implant) OR oblique implant) OR off angle implant) OR off-angle implant) OR implant angulation) OR malpositioned implant) OR tipped implant)) OR (((((upright implant) OR axial implant) OR parallel implant) OR straight implant) OR axially implant))) AND (((((("Dental Implant-Abutment Design"[Mesh]) OR "Dental Abutments"[Mesh])) OR (((((((((((((tilted abutment) OR angulated abutment) OR angled abutment) OR inclined abutment) OR offset abutment) OR non axial abutment) OR non axially abutment) OR non parallel abutments) OR oblique abutment) OR off angle abutment) OR off-angle abutment) OR abutment angulation) OR tipped abutment))) AND ((((((("Titanium"[Mesh]) OR "Gold"[Mesh]) OR "Aluminum"[Mesh]) OR "Ceramics"[Mesh]) OR "Zirconium"[Mesh])) OR ((((((((((ceramic) OR titanium) OR zirconia) OR polyetheretherketone) OR customized) OR custom) OR cad cam) OR CAD/CAM) OR metal) OR alumni)))

2.5 | Study selection

Study selection was performed in duplicate by two independent assessors (DB and KAAA). After the removal of duplicates, the titles and abstracts of potentially eligible studies were screened, followed by the selection of articles by reading their full-text. The articles that were judged to be eligible by their full-text in case all inclusion criteria were fulfilled, while disagreements between the two reviewers were resolved by discussion with a third person (SNP) to reach a consensus.

2.6 | Data collection process and data items

Two assessors (DB and KAAA) performed the data extraction in duplicate using Excel® (Microsoft Office 2017, Redmond, WA, USA) spreadsheets. Again, any disagreement was discussed with a third reviewer (SNP) to reach a consensus. Data extraction included study characteristics (authors and year of publication, setting and country of the center where the study was performed, study design, sample size, number of implants, implant system, number of tilted and axial implants, number of angulated or straight abutments, prosthetic fixation, abutment type, abutment angulation, type of restoration [fixed full-arch, fixed dental prosthesis, single crown], implant location, loading time, and follow-up in years) and data on measured outcomes. The primary outcome was the implant failure, whereas the secondary outcomes included mechanical complications, MBL, Pocket Probing Depth (PPD), and Clinical Attachment Loss (CAL).

2.7 | Risk of bias in individual studies

The risk of bias of the included non-randomized studies was assessed in duplicate by two authors (DB and KAAA) using the ROBINS-I tool.[18] The tool evaluates the risk of bias in seven domains: (i) confounding, (ii) selection of participants into the study, (iii) classification of interventions, deviations from intended interventions, (v) to missing data, (vi) measurement of outcomes, and (vii) bias in selection of the reported result. The risk of bias judgements was finally interpreted as (i) low risk of bias if the study was judged to be at low risk of bias for all domains; (ii) moderate risk of bias if the study was judged to be at low or moderate risk of bias for all domains; (iii) serious risk of bias if the study was judged to be at serious risk of bias in at least one domain, but not at critical risk of bias in any domain; (iv) critical risk of bias if the study was judged to be at critical risk of bias in at least one domain. Moreover, (v) no information was used if there were no clear indications that the study was at serious or critical risk of bias and there was a lack of information in one or more key domains of bias.

2.8 | Data synthesis, risk of bias across studies, and additional analyses

Data were summarized and considered suitable for pooling, if similar abutment types were compared and if similar outcomes were reported. For studies reporting on data before and after treatment, but not on the treatment-induced changes, we calculated those with a moderate pre-post correlation of 0.75. Relative risks (RRs) for binary outcomes or Mean differences (MDs) for continuous outcomes and their corresponding 95% confidence intervals (CIs) were calculated. The Number Needed to Treat (NNT) was used to clinically translate statistically significant RRs. As the effects of abutment angulation were deemed to be highly variable according to patient age, sex, oral hygiene, and individual variation of the implant's position, a random effects model was chosen over a fixed effect one to calculate the average distribution of treatment effects that can be expected.[19] A Restricted Maximum Likelihood (REML) random effects variance estimator was used instead of the older DerSimonian-Laird one, following recent guidance.[20] Random effects 95% predictions were calculated for meta-analyses with at least three studies to aid in their interpretation by quantifying expected treatment effects in a future clinical setting.[21] The extent and impact of between-study heterogeneity were assessed by inspecting the forest plots and by calculating the tau^2 and the I^2 statistics, respectively. The 95% CIs (uncertainty intervals) around tau^2 and I^2 were calculated to judge our confidence about these metrics. We arbitrarily adopted the I^2 thresholds of > 75% to be considered as signs of considerable heterogeneity, but we also judged the evidence for this heterogeneity (through the uncertainty intervals) and the localization on the forest plot. A two-tailed P value of 0.05 was considered significant for all hypothesis testing, except for a 0.10 used for the test of heterogeneity and reporting biases, which could ultimately not be performed. All analyses were run in Stata SE 14.0 (StataCorp, College Station, TX) by one author (SNP), and the study's dataset was openly provided.[22]

Subgroup analyses, meta-regressions, and assessments of reporting biases, and sensitivity analyses were initially planned in the review's protocol but could ultimately not be conducted due to limited number of included trials. Sensitivity analyses were performed by limiting the meta-analyses to only (a) prospective studies and (b) studies with a minimum of 200 implants (arbitrarily selected).

The overall quality of clinical recommendations (confidence in effects estimates) for each of the main outcomes was rated by using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) approach[23] using an improved summary of findings table format.[24] The minimal clinical important, large, and very large effects were conventionally defined as half, one, and two standard deviations for continuous outcomes[25] and as relative risks of 1.5, 2.5, or 5.0 for binary outcomes.[26] This assessment of the risk of bias for among trials was conducted independently by two authors (DB and KAAA), and discrepancies were resolved by discussion with a third author (SNP).

3 | RESULTS

3.1 | Study selection

The electronic search yielded 784 titles (Figure 1), and no new articles were added through the hand search. After the removal of the duplicates, 536 articles were screened by title and abstract, and 488 were excluded by both reviewers (DB and KAAA). The full-text assessment was performed on the remaining 48 articles. Thirty-nine articles (Appendix S2) were excluded because they did not meet the inclusion criteria and nine articles (Appendix S3) were included in the present systematic review (Figure 1). Most of the articles were excluded because the data on angulated abutments were not separated from those of the straight abutments. The agreement between the two reviewers was kappa >0.9.

3.2 | Study characteristics

The nine included studies were published between 2000 and 2018, with the majority being published after 2011 and reported data on 797 patients and 4127 implants (Table 1). Four studies included 20-50 patients, two included from 51-100 patients, and 3 presented cohorts exceeding >100 patients. Three studies included single crown restorations, five studies included partial FDPs, and eight studies included full-arch FDPs. Two thirds of the included studies (n=6; 66.6%) were retrospective and three were prospective (33.3%). Four studies included immediate loading, four studies included delayed loading, and one study included both. Six studies included a total of 1539 tilted implants and 1151 axial implants (Table 2). From three studies it was not possible to separate the data from the two different implant angulations. The implants were of five different systems.

The total number of abutments reported were 4079 of which 1673 were angulated, and 2406 straight (Table 2). The type of retention of the prosthesis was reported for 2433 abutments, all being of the screw-retained type. One study did not report the type of fixation[27]. Eight studies reported the use of 3998 prefabricated, while one study did not report this data[10]. Five studies reported the angulation of 1442 abutments of which none had 15º, 1063 had 17º, and 379 had 30º degree of angulation.

3.3 | Risk of bias within studies

The risk of bias of the nine studies evaluated with the ROBINS-I tool revealed that three studies (33%) presented moderate risk of bias, while six studies (67%) were in serious risk of bias (Figure 2; Appendix S4). The domains that contributed to the judgment of serious risk of bias was for confounding reasons (>50%) and the bias in measurement of outcomes (>50%).

3.3 | Results of individual studies

3.3.1 | Implant failure

Three studies[7,28,29] reported implant failures that could be discriminated between being supported by straight or angulated abutments (Figure 3C). Fourteen implants supporting straight abutments and nine angulated abutments were lost during follow-up. In one study,[7] two failures of axial implants were reported, which were judged to be prior to loading and were excluded (Figure 3A). In another study (Malo 2016),[28] ninety-six angulated and ninety-three straight abutments were used. Five failures of implants supporting angulated abutments were reported. Two implants were lost during the first year of loading, two other implants shortly after 1 year, and one implant between 2-3 years of loading. Another study[29] used 18 angulated and 374 straight abutments were used and sixteen implant failures. Four events were reported for implants supporting angulated abutments and twelve supporting straight abutments. Seven failures occurred between 2 and 3 years, and nine between 3 and 4 years of loading.

3.3.2 | Mechanical and technical complications of abutments

Mechanical and technical complications were evaluated only the definitive prosthesis restorations. Three studies[27,30,31] reported differentiated data for angulated and straight abutments after 1 year of loading (Figure 3B). In one study,[30] seven events occurred at the angulated abutment, while no events were reported for the straight abutments. In another study (Araujo),[31] nine events occurred at the angulated abutments and 71 at the straight abutments. In another study (Aires),[27] eight events were registered, four were related to angulated abutments with 17º degrees of angle, and four were related to straight abutments. The failures were mostly associated to the retention screw while screw fracture was the second most frequent event. Two of the included papers[7,29] reported failures of the abutments without discriminating between angulated and straight abutments.

3.3.3 | Biological complications of abutments

Three studies[5-7] reported data of MBL after 1 year, two studies after 2 and 3 years[5,7] and only one study[29] reported data after 5 years of follow-up (Figure 3C).

After one year of follow-up, one study[7] reported a mean MBL of 0.57±0.50 mm and 0.43±0.45 mm for angulated and straight abutments, respectively. Another study reported an MBL of 1.01±0.37 mm and 0.94±0.38 mm for angulated and straight abutment, respectively. The third study reported 0.70±0.40 mm and 0.60±0.30 mm of MBL, respectively. The mean values of the three studies were 0.74±0.25 mm and 0.66±0.26 mm for angulated and straight abutments, respectively. The difference was statistically significant.

Only one study reported differentiated data on probing depth and clinical attachment level (Eger)[10]. Twenty-four patients were restored with 56 angulated abutments and 25 straight abutments, but no statistically significant differences were found for probing depth or buccal attachment level at any period evaluated.

3.3.4 | Mechanical complications of prostheses

For mechanical complications of prostheses, it was not possible to discriminate the data between angulated and straight abutments. Nine studies evaluated the technical complications of FDPs and reported overall survival rates of 99.4% after 1 year, 99.6% after 3 year, and 99.0% after 5 years of follow-up. One study reported two failures due to frame fractures.[27]

Prosthetic screw loosening was the most frequent complication that was reported in four studies.[7,28,29,31] Chipping veneering was reported in two studies, mostly related to ceramic reconstructions[5,28] and teeth fracture in three studies,[7,27,28] mostly related to acrylic reconstructions.

3.3.5 | PROMs (Patient Reported Outcomes Measures)

For PROMs, it was not possible to discriminate the data between angulated and straight abutments. Two studies reported PROMs using questionnaires. In one study,[6] esthetics, phonetics, and function were reported after 6, 12, and 24 months and a high degree of patient's satisfaction of the treatment was achieved for all participants. In the second study,[5] the questionnaire revealed that all patients were very satisfied for esthetics, phonetics, and function.

3.4 | Synthesis of results

The results for the primary and secondary outcomes reported in all included studies, including meta-analyses of at least two studies, can be seen in Table 3. As far as the primary outcome is concerned, angulated abutments were associated with statistically significantly increased implant failure rates (2 studies; RR=7.3; 95% CI=2.8 to 19.1; $P < 0.001$) with low heterogeneity ($I^2 = 0\%$) (Figure 3A). This corresponds to absolute failure risks of 11.7% and 1.6% for angulated and straight abutments, respectively. Additionally, this translates to an NNT of 10 and means that every 10th implants that receive an angulated abutment instead of a straight one would fail, whereas it would have survived with a straight abutment – which is a clinically relevant effect.

Additionally, angulated abutments were associated with a statistically significant increase in MBL 1 year after insertion compared to straight abutments (3 studies; MD=0.08 mm; 95% CI=0.01 to 0.14 mm; P=0.02), which might be however clinically negligible (Figure 3C). One study indicated that angulated abutments had also higher MBL 2 years post-insertion (1 study; MD=0.11 mm; 95% CI=0.03

to 0.19 mm; P=0.006). Finally, one study indicated that angulated abutments were associated with increased CAL around the implants compared to straight abutments both 1 year post-insertion (1 study; MD=0.30 mm; 95% CI=0.10 to 0.50 mm; P=0.003) or 2 years post-insertion (1 study; MD=0.63 mm; 95% CI=0.38 to 0.89 mm; P<0.001).

No statistically significant difference in the rate of mechanical complications was found between angulated and straight abutments (3 studies; RR=0.91; 95% CI=0.51 to 1.64; P=0.76) with no heterogeneity across studies. The same finding was observed when looking at mechanical complications in the long-term with follow-up of at least 5 years (1 study; RR=1.05; 95% CI=0.52 to 2.13; P=0.89).

The quality of evidence however according to the GRADE approach was very low for all cases (Appendix S5), which means that our confidence is these results is very poor and future studies might substantially change these recommendations. The main reasons for downgrading the evidence quality was bias associated with the inclusion of non-randomized studies with poor design and imprecision due to the inclusion of studies with inadequate sample sizes.

3.5 | Sensitivity analyses

Sensitivity analyses could ultimately be performed by limiting analyses to (a) prospective studies and (b) large studies (arbitrarily judged as those with more than 200 implants) (Appendix S6). Sensitivity analyses for implant failure indicated that angulated abutments were associated with significantly higher failure rates compared to straight abutment (1 study; RR=6.7; 95% CI=2.5-19.3), which was supported by both sensitivity analyses and contrary to the original analysis was statistically significant (P<0.001). No other considerable differences were found for mechanical complications or cumulative MBL, where the sensitivity analyses could either not be performed or were consistent with the original analysis.

4 | DISCUSSION

The present systematic review appraises critically existing evidence from clinical studies comparing angulated to straight abutments for oral rehabilitation with dental implants. A total of 9 non-randomized cohort studies (3 prospective and 6 retrospective) including partially / totally edentulous patients treated with dental implants restored with angulated and / or straight abutments. However, in the majority of the studies included in the present review, the authors did not provide clearly separate data on implant loss according to abutment type, which precluded formally using them in meta-analysis. As a results only two studies with eligible data were pooled through meta-analysis.[28,29] After one year of loading, the risk for implant failure was considerably higher for angulated abutments compared to straight abutments (11.7% and 1.6%, respectively)– an effect that was both statistically significant and clinically relevant. This is in contrast to a previous systematic review with meta-analysis on biological and technical complications of tilted compared to straight implants.[4] That review included 17 non-randomized studies with 7,568 implants installed in 1,849 patients to supporting full-arch or FDPs were evaluated and found high survival rates for both tilted implants (95.0%–100%) or straight implants (87.5%–100%), but found no statistically significant difference. Nevertheless, in the present study, the combination of the two components, tilted implants and angulated abutments, resulted in a statistically significant and clinically relevant higher implant loss for the latter. This might be due to either eccentric loading of the implant and the subsequent distribution of stresses or due to microbiological factors pertaining to the peri-implant area.

Mechanical complications of the implant abutments were reported in three studies,[27,30,31] but no significant differences were found according to abutment type. The most reported abutment complications in the included studies were screw loosening and screw fractures. In another systematic review assessing cemented and screw-retained fixed prostheses supported by implants,[14] the most frequent technical complication in all types of fixed restorations was the loosening of the abutment and/or of the restoration screws. However, data from the studies included in this review did not allow data synthesis, due to incomplete reporting. . In another systematic review on fixed dental prostheses supported by implants,[2] the influence of the implant-abutment connection on the clinical outcomes were evaluated for metal and ceramic abutments. The predominant technical complications were abutment screw loosening and screw fractures, especially in case of external implant-abutment connection. Finally, in a recent review,[32] factor contributing to loosening of implant abutment screws were evaluated and it was reported that the internal connection and abutments with anti-rotational design presented lower risk of screw loosening.

The data on marginal bone loss after one year were extracted from three studies[5-7] two of which were referring to immediately loaded implants and one followed the conventional loading. After one year of loading, the MBL was 0.74 mm at the angulated abutments, and 0.66 mm at the straight abutments.

The difference (0.08 mm) was statistically significant (p 0.02), however with a low clinical relevance with the data slightly in favor of straight abutments. In a systematic review on different loading protocols,[33] the lowest marginal bone loss after one year from implant installation was found for immediately loaded implants (0.05 mm) while the highest was registered for implants non-occlusally loaded (1.37 mm). For the conventional loading, the mean marginal bone loss was 0.85 mm. In a previous reported systematic review,[4] the marginal bone loss after 3-10 years of follow-up ranged between 0.5 mm and 1.9 mm for straight implants, and between 0.4 mm and 2.0 mm for tilted implants. In any case, the results of the current review indicate that a difference in MBL of 0.08 mm between angulated and straight abutments might not be of considerable clinical relevance.

Several factors related to the abutments may have affected the amount of marginal bone loss. The height of the abutments may influence the bone level in the early and late periods of healing[12] while the abutment material has been shown to have a low influence on marginal bone level.[34] An external implant-abutment connection presented higher marginal bone loss compared to an internal connection,[35,36] that was mostly related to the platform switching concept.[37] The repeated abutment disconnection and re-connection as well has been shown to increase marginal bone loss.[38] In the present systematic review, this complementary information was mostly missing so that it was not possible to extract sufficient data to allow further analyses.

The overall survival rate of the prosthesis reconstruction reported by eight studies was 99.4% after 1 year, 99.6% after 3 year, and 99.0% after 5 years of follow-up. It must be considered that the differentiation among angulated and straight abutments could not be performed. The prosthetic screw loosening was the most reported complication[7,28,29,31] followed by veneer chipping of ceramic restoration[5,28] and tooth fracture that mainly occurred in the acrylic restoration.[7,27,28,31] In another systematic review that evaluated the outcomes of ceramic vs. metal ceramic restorations on implants, chipping and ceramic fractures were the most reported complications.[36] However, the studies selected in that review were mostly cemented while in the present study all prostheses were screw-retained. One study reported a failure due to frame fractures.[27]

Only two studies reported PROMs, and both reported a high degree of patients' satisfaction regarding the restoration.[5,6]

As limitation of the present systematic review, the fact that few studies provided outcome data separately for angulated and straight abutments must be mentioned. Another limitation is that two thirds of the included studies presented serious risk of bias. Moreover, the meta-analysis was restricted to the one-year data, while little information was available for the following years of follow-up, fact that did not allow any further meta-analysis. One year of follow up is certainly of limited interest in a clinical perspective and further data on the implants long-term performance are needed. Yet, a statistically significant difference in favor of straight abutments was revealed for marginal bone loss after 1 year of follow-up. Finally, the results of the present review might be applicable to partially or totally edentulous patients of European / American origin treated in private practices or university clinics with straight or angulated abutments and pertain to the short- to mid-term outcome of the used implants.

5 | CONCLUDING REMARKS

A statistically and clinically relevant higher implant loss was disclosed for implant supporting angulated compared to straight abutments. Similar mechanical abutment complications were seen between angulated and straight abutments. The failures were mostly associated to the retention screw while screw fracture was the second most frequent event. Angulated abutments were associated with a statistically significant increase in MBL 1 year after insertion compared to straight abutments, however with a difference between groups of limited clinical interest.

Acknowledgements

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FIGURE LEGENDS

Figure 1 Flowchart.

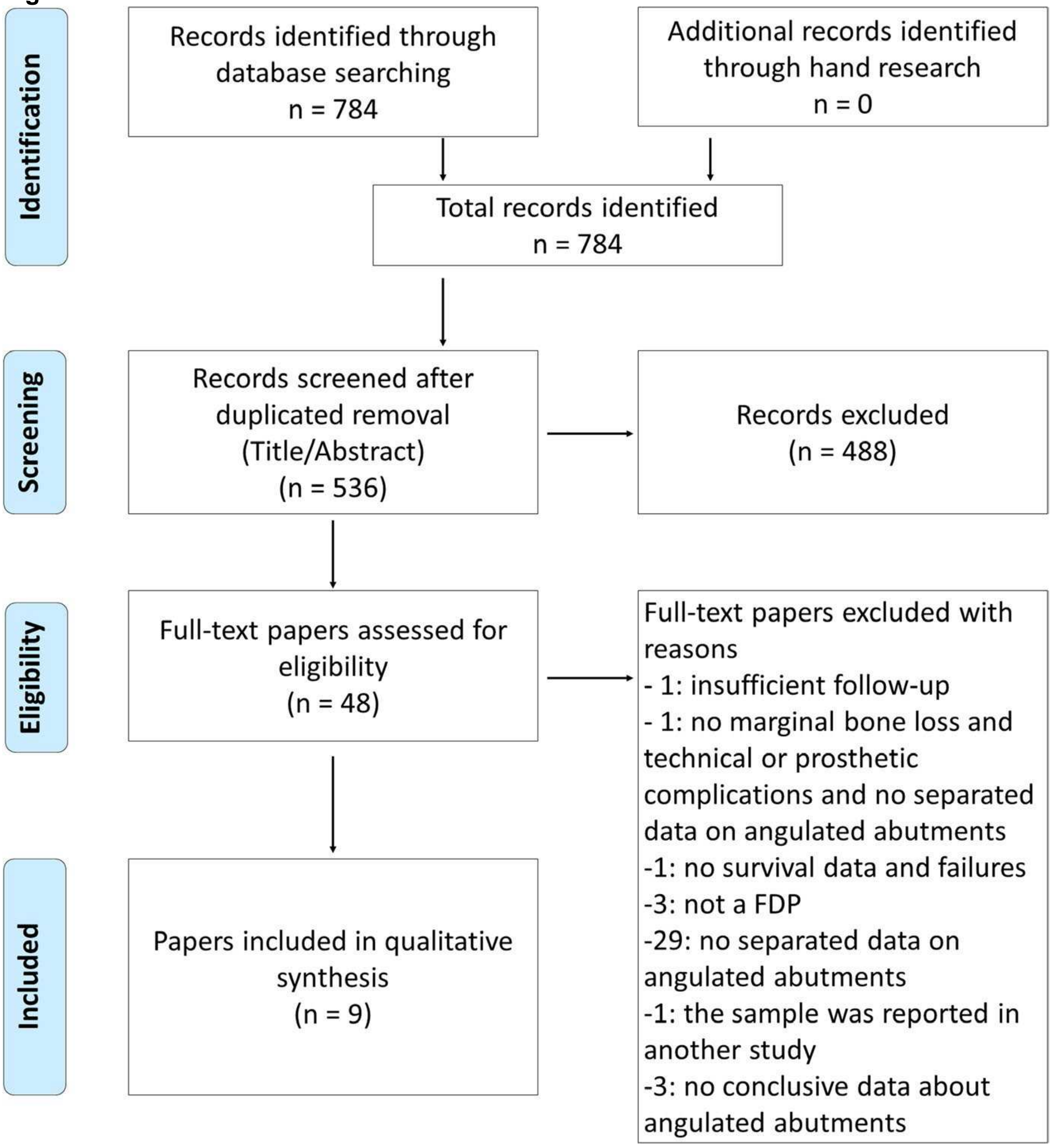


Figure 2 Graph illustrating the risk of bias of the thirteen non-randomized studies performed adopting the ROBINS-I tool.

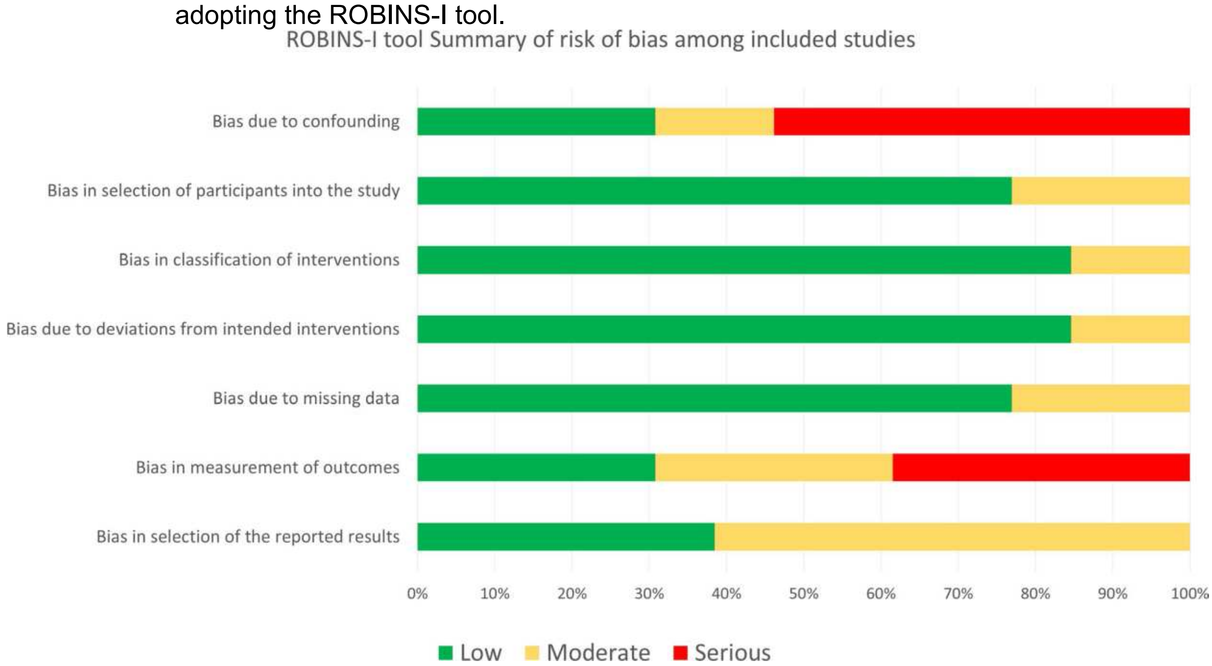
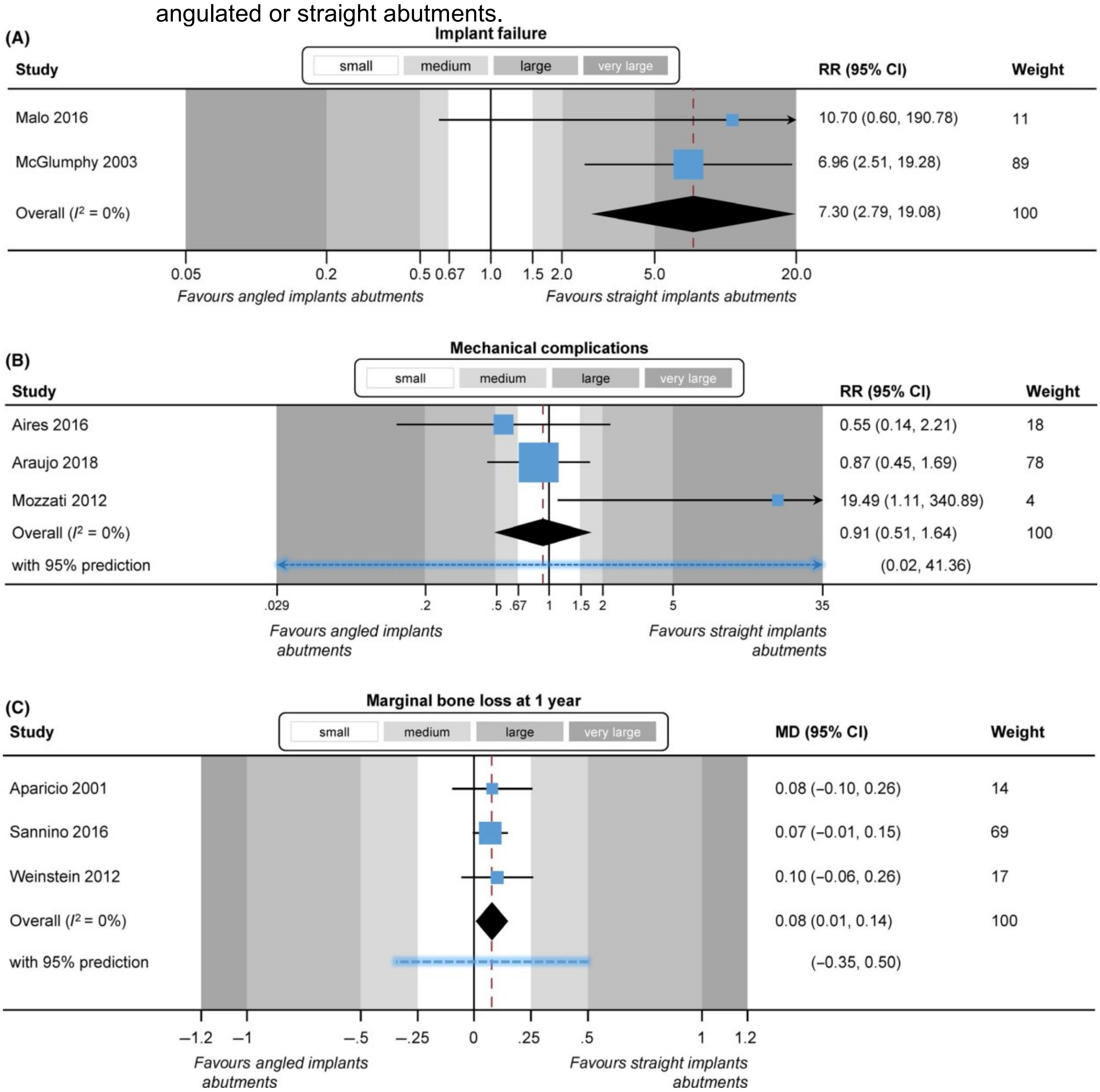


Figure 3 Contour-enhanced forest plot of random-effects meta-analysis of (A) implant failure, (B) mechanical complications, and (C) cumulative marginal bone loss at 1 year between angulated or straight abutments.



Appendix S1. Electronic search strategy.		
Database	Electronic Search strategy employed	Hits up to January 2019
PubMed	Search (((((((("Mouth, Edentulous"[Mesh]) OR "Jaw, Edentulous"[Mesh]) OR "Jaw, Edentulous, Partially"[Mesh]) OR "Alveolar Bone Loss"[Mesh])) OR (((((((((((((((edentulous maxilla) OR partial edentulism) OR partial edentulous jaws) OR fully edentulous jaws) OR edentulous jaws) OR edentulous mandible) OR edentulous patients) OR atrophic maxilla) OR atrophy maxilla) OR atrophied maxilla) OR atrophied mandible) OR atrophic jaws) OR total edentulous) OR partially edentulous) OR complete edentulism))) OR ((((("Denture Design"[Mesh]) OR "Denture, Partial, Fixed"[Mesh]) OR "Dental Prosthesis Design"[Mesh])) OR (("Dental Prosthesis, Implant-Supported"[Mesh]) OR full arch implant supported) OR full arch fixed prosthesis) OR full-arch fixed prosthesis) OR full-arch implant supported fixed prosthesis) OR dental implant prosthesis) OR fixed implant prosthodontics) OR hybrid implant prostheses) OR implant prosthesis) OR implant supported fixed prosthesis) OR implant supported fixed prostheses) OR fixed implant prostheses) OR implant prostheses) OR implant-supported fixed dental prostheses) OR implant-supported restoration) OR implant-supported fixed partial dentures) OR maxillary implant supported prosthesis) OR dental implant rehabilitation) OR screw retained prosthesis) OR fixed implant prosthesis) OR all-on-four) OR all-on-4) OR all on four) OR all on 4) OR all-on-six) OR all-on-6) OR all on six) OR all on 6) OR all on 4 dental implants) OR all-on-four) OR all on four dental implants) OR all-on-six dental implants) OR all-on-6 dental implants) OR all on six dental implants) OR all on 6 dental implants) OR fixed restoration) OR fixed prosthodontics) OR implant supported) OR fixed partial dentures) OR fixed dental prosthesis) OR fixed dental prostheses))) AND ((((((((((((((((tilted implant) OR angulated implant) OR angled implant) OR inclined implant) OR offset implant) OR non axial implant) OR non axially implant) OR non parallel implant) OR oblique implant) OR off angle implant) OR off-angle implant) OR implant angulation) OR malpositioned implant) OR tipped implant)) OR (((((upright implant) OR axial implant) OR parallel implant) OR straight implant) OR axially implant))) AND (((((("Dental Implant-Abutment Design"[Mesh]) OR "Dental Abutments"[Mesh])) OR (((((((((((((tilted abutment) OR angulated abutment) OR angled abutment) OR inclined abutment) OR offset abutment) OR non axial abutment) OR non axially abutment) OR non parallel abutments) OR oblique abutment) OR off angle abutment) OR off-angle abutment) OR abutment angulation) OR tipped abutment))) AND ((((((("Titanium"[Mesh]) OR "Gold"[Mesh]) OR "Aluminum"[Mesh]) OR "Ceramics"[Mesh]) OR "Zirconium"[Mesh])) OR ((((((((((ceramic) OR titanium) OR zirconia) OR polyetheretherketone) OR customized) OR custom) OR cad cam) OR CAD/CAM) OR metal) OR alumni)))	289
EMBASE	('edentulousness'/exp OR 'edentulousness' OR 'mouth disease'/exp OR 'mouth disease' OR 'diagnosis, oral'/exp OR 'diagnosis, oral' OR 'mouth, edentulous'/exp OR 'mouth, edentulous' OR 'edentulous jaw'/exp OR 'edentulous jaw' OR 'partial edentulism' OR 'partial edentulous jaw' OR 'total edentulism' OR 'jaw atrophy' OR 'atrophic mandible' OR 'atrophic jaw' OR 'edentulous patient'/exp OR 'edentulous	16

	patient' OR 'atrophic maxilla' OR 'atrophied mandible' OR 'total edentulous' OR 'partially edentulous' OR 'tooth prosthesis'/exp OR 'tooth prosthesis' OR 'fixed partial denture'/exp OR 'fixed partial denture' OR 'partial denture'/exp OR 'partial denture' OR 'implant-supported denture'/exp OR 'implant-supported denture' OR 'full mouth rehabilitation'/exp OR 'full mouth rehabilitation' OR 'full arch implant supported' OR 'dental implant prosthesis' OR 'fixed implant prosthodontics' OR 'hybrid implant prosthesis' OR 'implant prosthesis' OR 'implant-supported fixed dental prosthesis' OR 'implant-supported restoration' OR 'implant-supported fixed partial dentures' OR 'maxillary implant supported prosthesis' OR 'dental implant rehabilitation' OR 'all on four' OR 'all on 4' OR 'all on six' OR 'all on 6' OR 'malo all-on-four') AND ('tilted implant' OR 'angulated implant' OR 'angled implant' OR 'inclined implant' OR 'offset implant' OR 'non axial implant' OR 'non axially implant' OR 'non parallel implant' OR 'oblique implant' OR 'off angle implant' OR 'off-angle implant' OR 'implant angulation' OR 'malpositioned implant' OR 'tipped implant' OR 'upright implant' OR 'axial implant' OR 'parallel implant' OR 'straight implant' OR 'axially implant') AND ('dental abutment'/exp OR 'dental abutment' OR 'ankylos'/exp OR 'ankylos' OR 'prounic'/exp OR 'prounic' OR 'dental implant abutment'/exp OR 'dental implant abutment' OR 'dental implant abutment design'/exp OR 'dental implant abutment design' OR 'dental implant-abutment design'/exp OR 'dental implant-abutment design' OR 'tooth implant abutment'/exp OR 'tooth implant abutment' OR 'dental abutments'/exp OR 'dental abutments' OR 'titled abutment' OR 'angulated abutment' OR 'angled abutment' OR 'inclined abutment' OR 'offset abutment' OR 'off-set abutment' OR 'non axial abutment' OR 'non axially abutment' OR 'non parallel abutment' OR 'non-axial abutment' OR 'non-axially abutment' OR 'non-parallel abutment' OR 'oblique abutment' OR 'off angle abutment' OR 'off-angle abutment' OR 'abutment angulation' OR 'tipped abutment') AND ('titanium'/exp OR 'titanium' OR 'gold'/exp OR 'gold' OR 'aluminum'/exp OR 'aluminum' OR 'ceramics'/exp OR 'ceramics' OR 'zirconium'/exp OR 'zirconium' OR 'metal ceramic alloy'/exp OR 'metal ceramic alloy' OR 'polyetheretherketone'/exp OR 'polyetheretherketone' OR 'ceramic'/exp OR ceramic OR 'zirconia'/exp OR zirconia OR customized OR custom OR 'cad cam' OR 'metal'/exp OR 'metal')	
Web of Science	TS=("Mouth, Edentulous" OR "Jaw, Edentulous" OR "Jaw, Edentulous, Partially" OR "Alveolar Bone Loss"OR edentulous maxilla OR partial edentulism OR partial edentulous jaws OR fully edentulous jaws OR edentulous jaws OR edentulous mandible OR edentulous patients OR atrophic maxilla OR atrophy maxilla OR atrophied maxilla OR atrophied mandible OR atrophic jaws OR total edentulous OR partially edentulous OR complete edentulism) OR TS=("Denture Design" OR "Denture, Partial, Fixed" OR "Dental Prosthesis Design"OR "Dental Prosthesis, Implant-Supported" OR full arch implant supported OR full arch fixed prosthesis OR full-arch fixed prosthesis OR full-arch implant supported fixed prosthesis OR dental implant prosthesis OR fixed implant prosthodontics OR hybrid implant prostheses OR implant prosthesis OR implant supported fixed prosthesis OR implant supported fixed prostheses OR fixed implant prostheses OR implant prostheses OR implant-supported fixed dental prostheses OR implant-supported	479

	restoration OR implant-supported fixed partial dentures OR maxillary implant supported prosthesis OR dental implant rehabilitation OR screw retained prosthesis OR fixed implant prosthesis OR all-on-four OR all-on-4 OR all on four OR all on 4 OR all-on-six OR all-on-6 OR all on six OR all on 6 OR all on 4 dental implants OR malo all-on-four OR all on four dental implants OR all-on-six dental implants OR all-on-6 dental implants OR all on six dental implants OR all on 6 dental implants OR fixed restoration OR fixed prosthodontics OR implant supported OR fixed partial dentures OR fixed dental prosthesis OR fixed dental prostheses) AND TS=(tilted implant OR angulated implant OR angled implant OR inclined implant OR offset implant OR non axial implant OR non axially implant OR non parallel implant OR oblique implant OR off angle implant OR off-angle implant OR implant angulation OR malpositioned implant OR tipped implant) OR TS=(upright implant OR axial implant OR parallel implant OR straight implant OR axially implant) AND TS=("Dental Implant-Abutment Design" OR "Dental Abutments" OR tilted abutment OR angulated abutment OR angled abutment OR inclined abutment OR offset abutment OR non axial abutment OR non axially abutment OR non parallel abutments OR oblique abutment OR off angle abutment OR off-angle abutment OR abutment angulation OR tipped abutment) AND TS=("Titanium" OR "Gold" OR "Aluminum" OR "Ceramics" OR "Zirconium" OR ceramic OR titanium OR zirconia OR polyetheretherketone OR customized OR custom OR cad cam OR CAD/CAM OR metal OR alumni)	
	TOTAL	784
OpenGrey www.opengrey.eu	Abutment, angulated abutment, straight abutment	0

Appendix S2. Excluded text after full-text reading.

Full-text excluded studies	**Reason for exclusion**
Andriessen, F. S., Rijkens, D. R., Van Der Meer, W. J., & Wismeijer, D. W. (2014). Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: A pilot study. *Journal of Prosthetic Dentistry*, *111*(3), 186–194. https://doi.org/10.1016/j.prosdent.2013.07.010	It is dealing with overdentures
Aparicio, C., Ouazzani, W., Aparicio, A., Fortes, V., Muela, R., Pascual, A., … Franch, M. (2010). Extrasinus zygomatic implants: Three year experience from a new surgical approach for patients with pronounced buccal concavities in the edentulous maxilla. *Clinical Implant Dentistry and Related Research*, *12*(1), 55–61. https://doi.org/10.1111/j.1708-8208.2008.00130.x	No MBL reported, No Survival rate of the prosthesis and implants is reported.
Bressan, E., Grusovin, M. G., D'Avenia, F., Neumann, K., Sbricoli, L., Luongo, G., & Esposito, M. (2017). The influence of repeated abutment changes on peri-implant tissue stability: 3-year post-loading results from a multicentre randomised controlled trial. *European Journal of Oral Implantology*, *10*(4), 373–390.	No differentiate data about angulated and straight abutments
Brown, S. D. K., & Payne, A. G. T. (2011). Immediately restored single implants in the aesthetic zone of the maxilla using a novel design: 1-year report. *Clinical Oral Implants Research*, *22*(4), 445–454. https://doi.org/10.1111/j.1600-0501.2010.02125.x	No report anything about angled abutments
Cannizzaro, G., Felice, P., Soardi, E., Ferri, V., Leone, M., Lazzarini, M., … Esposito, M. (2013). Immediate loading of 2(all-on-2) versus 4 (all-on-4) implants placed with a flapless technique supporting mandibular cross-arch fixed prostheses: 1-year results from a pilot randomised controlled trial. *European Journal of Oral Implantology*, *6*(2 CC-Oral Health), 121-131. Retrieved from https://www.cochranelibrary.com/central/doi/10.1002/central/CN-00871555/full	No differentiate data about angulated and straight abutments
Cannizzaro, G., Loi, I., Viola, P., Ferri, V., Leone, M., Trullenque-Eriksson, A., & Esposito, M. (2016). Immediate loading of two (fixed-on-2) versus three (fixed-on-3) implants placed flapless supporting cross-arch fixed prostheses: One-year results from a randomised controlled trial. *Eur J Oral Implantol*, *9 Suppl 1*(2), 143–153. https://doi.org/36389 [pii]	No differentiate data about angulated and straight abutments
Canullo, L., Rosa, J. C., Pinto, V. S., Francischone, C. E., & Götz, W. (2012). Inward-inclined implant platform for the amplified platform-switching concept: 18-month follow-up report of a prospective randomized matched-pair controlled trial. *The International Journal of Oral & Maxillofacial Implants*, *27*(4), 927–34. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22848896	No differentiate data about angulated and straight abutments

Carrillo de Albornoz, A., Vignoletti, F., Ferrantino, L., Cardenas, E., De Sanctis, M., Sanz, M., … Sanz, M. (2014). A randomized trial on the aesthetic outcomes of implant-supported restorations with zirconia or titanium abutments. *Journal of Clinical Periodontology*, *41*(12), 1161–1169. https://doi.org/10.1111/jcpe.12312	No differentiate data about angulated and straight abutments
Crespi, R., Vinci, R., Cappare, P., Romanos, G. E., & Gherlone, E. (2012). A clinical study of edentulous patients rehabilitated according to the “all on four” immediate function protocol. The International Journal of Oral & Maxillofacial Implants, 27(2), 428–434. https://doi.org/15366 [pii]	No differentiate data about angulated and straight abutments
Degidi, M., Nardi, D., & Piattelli, A. (2010). Immediate loading of the edentulous maxilla with a definitive restoration supported by an intraorally welded titanium bar and tilted implants. *The International Journal of Oral & Maxillofacial Implants*, *25*(6), 1175–1182.	No differentiate data about angulated and straight abutments
Drago, C. (2018). Ratios of Cantilever Lengths and Anterior-Posterior Spreads of Definitive Hybrid Full-Arch, Screw-Retained Prostheses: Results of a Clinical Study. *Journal of Prosthodontics-Implant Esthetic and Reconstructive Dentistry*, *27*(5), 402–408. https://doi.org/10.1111/jopr.12519	No differentiate data about angulated and straight abutments
Esposito, M., Bressan, E., Grusovin, M. G., D’Avenia, F., Neumann, K., Sbricoli, L., & Luongo, G. (2017). Do repeated changes of abutments have any influence on the stability of peri-implant tissues? One-year post-loading results from a multicentre randomised controlled trial. *European Journal of Oral Implantology*, *10*(1), 57–72. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/28327695	No differentiate data about angulated and straight abutments
Esposito, M., Grusovin, M. G., Pellegrino, G., Soardi, E., & Felice, P. (2012). Safety and effectiveness of maxillary early loaded titanium implants with a novel nanostructured calcium-incorporated surface (Xpeed): 1-year results from a pilot multicenter randomised controlled trial. *European Journal of Oral Implantology*, *5*(3), 241–249.	No differentiate data about angulated and straight abutments
Feichtinger, M., Gaggl, A., Schultes, G., & Karcher, H. (2003). Evaluation of distraction implants for prosthetic treatment after vertical alveolar ridge distraction: a clinical investigation. *The International Journal of Prosthodontics*, *16*(1), 19–24.	10 restored with removable prosthesis
Glibert, M., De Bruyn, H., & Östman, P.-O. (2016). Six-Year Radiographic, Clinical, and Soft Tissue Outcomes of Immediately Loaded, Straight-Walled, Platform-Switched, Titanium-Alloy Implants with Nanosurface Topography. *The International Journal of Oral & Maxillofacial Implants*, *31*(1), 167–171. https://doi.org/10.11607/jomi.4162	No differentiate data about angulated and straight abutments

Gothberg, C., Andre, U., Grondahl, K., Ljungquist, B., Thomsen, P., & Slotte, C. (2014). Immediately loaded implants with or without abutments supporting fixed partial dentures: 1-year results from a prospective, randomized, clinical trial. *Clinical Implant Dentistry and Related Research*, *16*(4), 487–500. https://doi.org/10.1111/cid.12025	No differentiate data about angulated and straight abutments
Jokstad, A., Ellner, S., & Gussgard, A. (2011). Comparison of two early loading protocols in full arch reconstructions in the edentulous maxilla using the Cresco prosthetic system: A three-arm parallel group randomized-controlled trial. *Clinical Oral Implants Research*, *22*(5), 455–463. https://doi.org/10.1111/j.1600-0501.2010.02156.x	No differentiate data about angulated and straight abutments
Koo, K.-T., Lee, E.-J., Kim, J.-Y., Seol, Y.-J., Han, J. S., Kim, T.-I., … Rhyu, I.-C. (2012). The Effect of Internal Versus External Abutment Connection Modes on Crestal Bone Changes Around Dental Implants: A Radiographic Analyes. *Journal of Periodontology*, *83*(9), 1104–1109. https://doi.org/10.1902/jop.2011.110456	No differentiate data about angulated and straight abutments
Kutan, E., Bolukbasi, N., Yildirim-Ondur, E., & Ozdemir, T. (2015). Clinical and Radiographic Evaluation of Marginal Bone Changes around Platform-Switching Implants Placed in Crestal or Subcrestal Positions: A Randomized Controlled Clinical Trial. *Clinical Implant Dentistry and Related Research*, *17 Suppl 2*, e364-75. https://doi.org/10.1111/cid.12248	No differentiate data about angulated and straight abutments
Li, W., Chow, J., Hui, E., Lee, P. K. M., & Chow, R. (2009). Retrospective Study on Immediate Functional Loading of Edentulous Maxillas and Mandibles With 690 Implants, Up to 71 Months of Follow-Up. *Journal of Oral and Maxillofacial Surgery*, *67*(12), 2653–2662. https://doi.org/10.1016/j.joms.2009.07.015	No differentiate data about angulated and straight abutments
Lops, D., Parpaiola, A., Paniz, G., Sbricoli, L., Magaz, V. R., Venezze, A. C., … Stellini, E. (2017). Interproximal Papilla Stability Around CAD/CAM and Stock Abutments in Anterior Regions: A 2-Year Prospective Multicenter Cohort Study. International Journal of Periodontics & Restorative Dentistry, 37(5), 657–666. https://doi.org/10.11607/prd.3184	No conclusive about abutment inclination
Luongo, G., Bressan, E., Grusovin, M. G., D'Avenia, F., Neumann, K., Sbricoli, L., & Esposito, M. (2015). Do repeated changes of abutments have any influence on the stability of peri-implant tissues? Four-month post-loading preliminary results from a multicentre randomised controlled trial. *European Journal of Oral Implantology*, *8*(2), 129–140. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ddh&AN=103069432&site=ehost-live	No differentiate data about angulated and straight abutments
Malo, P., Mde, A. N., Petersson, U., & Wigren, S. (2006). A pilot study of complete edentulous rehabilitation with immediate function using a new implant design: case series. *Clinical Implant Dentistry and Related Research*, *8*(4), 223–232.	No differentiated MBL for angulated and straight abutments, no technical complications reported
Malo, P., de Araujo Nobre, M., Lopes, A., Francischone, C., & Rigolizzo, M. (2012). "All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes. Clinical Implant Dentistry and Related Research, 14 Suppl 1, e139-50. https://doi.org/10.1111/j.1708-8208.2011.00395.x	No differentiate data about angulated and straight abutments

Mericske-Stern, R., Grutter, L., Rosch, R., & Mericske, E. (2001). Clinical evaluation and prosthetic complications of single tooth replacements by non-submerged implants. *Clinical Oral Implants Research*, *12*(4), 309–318.	No differentiate data about angulated and straight abutments
Naert, I., Koutsikakis, G., Quirynen, M., Duyck, J., van Steenberghe, D., & Jacobs, R. (2002). Biologic outcome of implant-supported restorations in the treatment of partial edentulism - Part 2: A longitudinal radiographic evaluation. *Clinical Oral Implants Research*, *13*(4), 390–395. https://doi.org/10.1034/j.1600-0501.2002.130407.x	No differentiate data about angulated and straight abutments
Nickenig, H. J., Wichmann, M., Happe, A., Zöller, J. E., & Eitner, S. (2013). A 5-year prospective radiographic evaluation of marginal bone levels adjacent to parallel-screw cylinder machined-neck implants and rough-surfaced microthreaded implants using digitized panoramic radiographs. *Journal of Cranio-Maxillo-Facial Surgery : Official Publication of the European Association for Cranio-Maxillo-Facial Surgery*, *41*(7), 564–568. https://doi.org/10.1016/j.jcms.2012.11.027	No MBL reported, no differentiate data about angulated and straight abutments
Pancko, F., Dyer, J., Weisglass, S., & Kraut, R. A. (2010). Use of tilted implants in treatment of the atrophic posterior mandible: a preliminary report of a novel approach. *Journal of Oral and Maxillofacial Surgery : Official Journal of the American Association of Oral and Maxillofacial Surgeons*, *68*(2), 407–413.	No MBL reported, no differentiate data about angulated and straight abutments
Patil, R., Hartog, L., Heereveld, C., Jagdale, A., Dilbaghi, A., & Cune, M. (2014). Comparison of Two Different Abutment Designs on Marginal Bone Loss and Soft Tissue Development. *The International Journal of Oral & Maxillofacial Implants*, *29*(3), 675–681. https://doi.org/10.11607/jomi.3363	No survival data
Patil, R., van Brakel, R., Iyer, K., Slater, J. H., de Putter, C., & Cune, M. (2013). A comparative study to evaluate the effect of two different abutment designs on soft tissue healing and stability of mucosal margins. *Clinical Oral Implants Research*, *24*(3), 336–341. https://doi.org/10.1111/j.1600-0501.2011.02335.x	No 1-year data
Pegoraro, T., Bonfante, G., do Valle, A., Pegoraro, L., Ayub, K., & Ayub, E. (2017). Seven-Year Follow-up of Full-Arch Prostheses Supported by Four Implants: A Prospective Study. *The International Journal of Oral & Maxillofacial Implants*, *32*(6), 1351–1358. https://doi.org/10.11607/jomi.5312	No MBL, no survival data no 1-year data
Peng, M., Fei, W., Hosseini, M., & Gotfredsen, K. (2013). Influence of Implant Position on Clinical Crown Length and Peri-implant Soft Tissue Dimensions at Implant-Supported Single Crowns Replacing Maxillary Central Incisors. *International Journal of Periodontics & Restorative Dentistry*, *33*(6), 785–+.	No MBL reported, no differentiate data about angulated and straight abutments
Pozzi, A., Sannino, G., & Barlattani, A. (2012). Minimally invasive treatment of the atrophic posterior maxilla: a proof-of-concept prospective study with a follow-up of between 36 and 54 months. The Journal of Prosthetic Dentistry, 108(5), 286–297.	No conclusive about abutment inclination

Pozzi, A., Agliardi, E., Tallarico, M., & Barlattani, A. (2014). Clinical and radiological outcomes of two implants with different prosthetic interfaces and neck configurations: Randomized, controlled, split-mouth clinical trial. *Clinical Implant Dentistry and Related Research*, *16*(1), 96–106. https://doi.org/10.1111/j.1708-8208.2012.00465.x	No MBL reported, no differentiate data about angulated and straight abutments
Schwarz, F., Mihatovic, I., Becker, J., Bormann, K. H., Keeve, P. L., & Friedmann, A. (2013). Histological evaluation of different abutments in the posterior maxilla and mandible: An experimental study in humans. *Journal of Clinical Periodontology*, *40*(8), 807–815. https://doi.org/10.1111/jcpe.12115	No MBL reported, no differentiate data about angulated and straight abutments
Stein, A. E., McGlmphy, E. A., Johnston, W. M., & Larsen, P. E. (2009). Effects of implant design and surface roughness on crestal bone and soft tissue levels in the esthetic zone. *The International Journal of Oral & Maxillofacial Implants*, *24*(5), 910–919. JOUR.	No MBL reported, no differentiate data about angulated and straight abutments
Tealdo, T., Bevilacqua, M., Pera, F., Menini, M., Ravera, G., Drago, C., & Pera, P. (2008). Immediate function with fixed implant-supported maxillary dentures: a 12-month pilot study. *The Journal of Prosthetic Dentistry*, *99*(5), 351–360.	No MBL reported, no differentiate data about angulated and straight abutments
Todisco, M., Sbricoli, L., Ippolito, D. R., & Esposito, M. (2018). Do we need abutments a immediately loaded implants supporting cross-arch fixed prostheses? Results from a 5-year randomised controlled trial. European Journal of Oral Implantology, 11(4), 397–407.	No differentiate data about angulated and straight abutments
Veis, A., Parissis, N., Tsirlis, A., Papadeli, C., Marinis, G., & Zogakis, A. (2010). Evaluation of peri-implant marginal bone loss using modified abutment connections at various crestal level placements. *The International Journal of Periodontics & Restorative Dentistry*, *30*(6), 609–617. JOUR.	No MBL reported, no differentiate data about angulated and straight abutments

Appendix S3. Included study after full-text reading.

Aires, I., & Berger, J. (2016). Planning Implant Placement on 3D Stereolithographic Models Applied with Immediate Loading of Implant-Supported Hybrid Prostheses After Multiple Extractions: A Case Series. *The International Journal of Oral & Maxillofacial Implants*, *31*(1), 172–178. https://doi.org/10.11607/jomi.4186
Aparicio, C., Perales, P., & Rangert, B. (2001). Tilted implants as an alternative to maxillary sinus grafting: A clinical, radiologic, and periotest study. *Clinical Implant Dentistry and Related Research*, *3*(1), 39–49. https://doi.org/10.1111/j.1708-8208.2001.tb00127.x
Araújo, P. M., Bianchini, M. A., Ferreira, C. F., Filho, G. S., Cagna, D. R., & Magalhães Benfatti, C. A. (2018). Mechanical Complications Related to the Retention Screws of Prefabricated Metal Abutments With Different Angulations. *Implant Dentistry*, *27*(2), 1. https://doi.org/10.1097/id.0000000000000742
Eger, D. E., Gunsolley, J. C., & Feldman, S. (2000). Comparison of angled and standard abutments and their effect on clinical outcomes: a preliminary report. *The International Journal of Oral & Maxillofacial Implants*, *15*(6), 819–823.
Malo, P., de Araujo Nobre, M., Lopes, A., Ferro, A., & Gravito, I. (2016). Complete Edentulous Rehabilitation Using an Immediate Function Protocol and an Implant Design Featuring a Straight Body, Anodically Oxidized Surface, and Narrow Tip with Engaging Threads Extending to the Apex of the Implant: A 5-year Retrospective Clinica. *The International Journal of Oral & Maxillofacial Implants*, *31*(1), 153–161.
McGlumphy, E. A., Peterson, L. J., Larsen, P. E., & Jeffcoat, M. K. (2003). Prospective study of 429 hydroxyapatite-coated cylindric omniloc implants placed in 121 patients. *International Journal of Oral & Maxillofacial Implants*, *18*(1), 82–92.
Mozzati, M., Arata, V., Gallesio, G., Mussano, F., & Carossa, S. (2012). Immediate postextraction implant placement with immediate loading for maxillary full-arch rehabilitation A two-year retrospective analysis. *Journal of the American Dental Association*, *143*(2), 124–133.
Sannino, G., & Barlattani, A. (2016). Straight Versus Angulated Abutments on Tilted Implants in Immediate Fixed Rehabilitation of the Edentulous Mandible: A 3-Year Retrospective Comparative Study. *The International Journal of Prosthodontics*, *29*(3), 219–226. https://doi.org/10.11607/ijp.4448
Weinstein, R., Agliardi, E., Fabbro, M. D., Romeo, D., & Francetti, L. (2012). Immediate Rehabilitation of the Extremely Atrophic Mandible with Fixed Full-Prosthesis Supported by Four Implants. *Clinical Implant Dentistry and Related Research*, *14*(3), 434–441. https://doi.org/10.1111/j.1708-8208.2009.00265.x

Appendix S4. Details on the risk of bias assessment of included studies with the ROBINS-I tool.

Author	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported results	Overall bias	Risk of bias interpretation
Aires 2016	Serious	Moderate	Low	Moderate	Moderate	Serious	Moderate	Serious	**The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.**
	Confounding: At least one known important domain was not appropriately measured (not controlled for "smoking habit", despite it was mentioned, statistical analysis does not address it inthe survival data). Also, other possible counfounder may be the delayed prosthesis, the preexisting implants and some sleeping implants), that were not clearly explained in the statistical analysis.	The proportion of participants for which this was the case was too low to induce important bias. there was an atrision bias due of the sample when the study start and the follow up	Intervention status is well defined.	There were deviations described related to the placement of implants and delayed loading, also the preexisting implants from intented intervention, but their impact on the outcome is expected to be a risk factor	Proportions of and reasons for missing participants differ slightly across intervention group. Drop out and withdrawn during follow-up almost reach more than 30%. of implants	*It is probably that outcome was assessed by assessors aware of the intervention received by study participants *No blinded outcome assessor *No calibration process *Not enough described regarding outcome assessor implementation.	The outcome measurements and analyses are clearly defined		
Aparicio 2001	Serious	Moderate	Low	Low	Low	Serious	Moderate	Serious	**The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.**
	Confounding only: At least one known important domain was not appropriately measured (not controlled for "smoking habit", despite it was mentioned, statistical analysis does not address it. Also, other possible counfounder may be the opposing arch (natural teeth, implant supported fixed prostheses), that were not considered in statistical analysis.	*The proportion of participants for which this was the case was too low to induce important bias. The distribution among test and control group implants was assessed by means of chi-square test.	Intervention status is well defined.	Co-interventions not performed	*Proportions for missing data were similar across intervention groups.*The analysis addressed missing data and is likely to have removed any risk of bias.	*The outcome was assessed by assessors aware of the intervention received by study participants *No blinded outcome assessor *No calibration process	*There is no indication of the selection of the cohort or subgroups for analysis and reporting on the basis of the result (Not showed data regarding smoker patients		
Araujo 2018	Serious	Moderate	Low	Low	Low	Moderate	Low	Serious	**The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.**
	Confounding only: At least one known important domain was not appropriately measured (age, sex, ,smoking habit) . the inclusion and exclusion criteria were not well defined . Analysis not adjusted to risk factors or confounders.	Selection into the study may have been related to intervention and outcome	Intervention status is well defined.	Co-interventions not performed and not reported	Data were reasonably complete	*Calibration process described *No blinded outcome assessor described	*There is clear evidence that all reported results correspond to al intented outcomes, analyses and sub-cohorts		
Eger 2000	Serious	Moderate	Low	Low	Low	Serious	Moderate	Serious	**The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.**
	Confounding only: . Smokers, Opposing dentitition was not considered to be a discriminating factor (only edentulous patient were included) also parafunctional habits, that were not clearly explained in the statistical analysis.	Selection into the study may have been related to intervention and outcome	Intervention status is well defined.	Co-interventions not performed	Data were reasonably complete	*The outcome was assessed by assessors aware of the intervention received by study participants *No blinded outcome assessor *No calibration process *Not enough described regarding outcome assessor implementation.	*Outcome measurements and analyses are consistent with an a priori plan.*There is no indication of the selection of the cohort or subgroups for analysis and		

							reporting on the basis of the result		
Malo 2016	**Moderate**	**Moderate**	**Moderate**	**Low**	**Low**	**Low**	**Moderate**	**Moderate**	**The study is judged to be at low or moderate risk of bias for the majority of domains.**
	Confounding only: Reliability and validity of measuremnet of important domains were sufficient. current smoker were excluded. Male and Female patients were incliuded in equal distribution. Opposing dentitition was not considered to be a discriminating factor (only edentulous patient were included)	The exclusion criteria were poorly described. the inclusion criteria include patients with confunding factors.	Some aspects of the assignments of intervention status were determined retrospectively	Co-interventions not performed	Data were reasonably complete	*The outcome assessor were unaware of the intervention received by the study pariticpants. Blinded outcome assessors and calibration process were adequately described	*Outcome measurements and analyses are consistent with an a priori plan.*There is no indication of the selection of the cohort or subgroups for analysis and reporting on the basis of the result (Not showed data regarding smoker patients)		
Mc Glumphy 2003	**Low**	**Moderate**	**Low**	**Low**	**Low**	**Serious**	**Moderate**	**Serious**	**The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.**
	No confounding expected	The authors used appropriate methods to adjust for the selection bias.*The proportion of participants for which this was the case was too low to induce important bias.*All patients included have edentulous jaws.* Slight imbalances among male and female patients.*Implants were placed in submerged fashion.	Intervention status is well defined.	Co-interventions not performed	Data were reasonably complete	*No blinded outcome assessor *No calibration process *Not enough described regarding outcome assessor implementation.	*Outcome measurements and analyses are consistent with an a priori plan.*There is no indication of the selection of the cohort or subgroups for analysis and reporting on the basis of the result (Not showed data regarding smoker patients)		
Mozzati 2012	**Low**	**Low**	**Low**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**The study is judged to be at low or moderate risk of bias for all domains.**
	No confounding expected	All participants who would have been eligible for the target trial were included in the study. *All patients included have edentulous jaws.* Male and female patients were balanced appropriately. *Implants were placed in submerged fashion.	Intervention status is well defined.	Co-interventions not performed	Data were reasonably complete	two independet examiners measure but not blinded, there was a calibration process were adequately described	*Outcome measurements and analyses are consistent with an a priori plan.*There is no indication of the selection of the cohort or subgroups for analysis and reporting on the basis of the result (data regarding smoker patients or comorbidities was not considered in statistical analysis).		

Saninno 2016	Serious	Moderate	Low	Low	Moderate	Serious	Low	Serious	The study is judged to be at serious risk of bias in at least one domain, but not critical risk of bias in any domain.
	Confounding only: At least one known important domain was not appropriately measured parafunctional habits	The authors used appropriate methods to adjust for the selection bias.*The proportion of participants for which this was the case was too low to induce important bias.	Intervention status is well defined.	Intervention status is well defined.	Proportions of and reasons for missing participants differ slightly across intervention group. Drop out during follow-up almost reach the 20%.	*It is probably that outcome was assessed by assessors aware of the intervention received by study participants *No blinded outcome assessor *No calibration process *Not enough described regarding outcome assessor implementation.	*There is clear evidence that all reported results correspond to al intented outcomes, analyses and sub-cohorts		
Weinstein 2012	Low	Low	Low	Low	Moderate	Low	Low	Moderate	The study is judged to be at low or moderate risk of bias for all domains.
	No confounding expected	All participants who would have been eligible for the target trial were included in the study	Intervention status is well defined.	Co-interventions not performed	Proportions of and reasons for missing participants differ slightly across intervention group. Drop out during follow-up almost reach the 20%.	*The outcome assessor were unaware of the intervention received by the study pariticpants. Blinded outcome assessors and calibration process were adequately described	*There is clear evidence that all reported results correspond to al intented outcomes, analyses and sub-cohorts		

Appendix S5. Summary of findings table according to the GRADE approach.

Outcome Studies (implants)	RR (95% CI)	Anticipated absolute effects[a] Straight abutments[b]	Angled abutments	Difference	Quality of the evidence (GRADE)[c]	What happens
Implant failure 5 years 2 studies (581 implants)	7.3 (2.79 to 19.08)	1.6%	11.7% (4.5 to 30.5%	10.1% more implants (2.9% to 28.9% more)	⊕○○○ very low[d] due to bias	Might lead to increased increased implant failure
Mechanical complications 2-5 years 3 studies (3396 implants)	0.9 (0.51 to 1.64)	2.1%	1.9% (1.1% to 3.4%)	0.2% less implants (1.0% less to 1.3% more)	⊕○○○ very low[d] due to bias	Little to no difference in mechanical complications
Cumulative MBL 1 year 3 studies (505 implants)	-	0.7 mm	-	0.1 mm more (0 to 0.1 mm more)	⊕○○○ very low[d] due to bias	Might lead to increased marginal bone loss
CAL 2 years 1 study (48 implants)	-	3.0 mm	-	0.2 mm less (0 to 0.4 mm less)	⊕○○○ very low[d,e] due to bias, imprecision	Little to no difference in attachment levels
PPD 2 years 1 study (48 implants)	-	2.8 mm	-	0.6 mm more (0.4 to 0.9 mm more)	⊕○○○ very low[d,e] due to bias, imprecision	Might lead to increased probing depth

Angled versus straight abutments for dental implants.
Population & intervention: adult partially / totally edentulous patients in need of prosthetic rehabilitation.
Settings: university clinics or private practices / clinics (Italy, Portugal, Spain, USA).

[a] The basis for the response/risk in the control group (e.g., the average control group risk across studies) is provided in footnotes. The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
[b] Response/risk in the control group is based on random-effects meta-analysis of the average effect/event rate for straight abutments in the included studies.
[c] Starts from "low", due to the inclusion of non-randomized studies.
[d] Downgraded due to serious limitations (high risk of bias).
[e] Downgraded by one point for imprecision; limited sample size and/or wide confidence intervals for treatment effects.

CI, confidence interval; GRADE, Grading of Recommendations Assessment, Development and Evaluation; RR, relative risk.

Appendix S6. Results of individual studies and performed random-effects meta-analyses for the primary and secondary outcomes of this review.

	Original analysis				**Only prospective studies**				**Only studies with >200 implants**		
Outcome	**n**	**Effect (95% CI)**	**P**		**n**	**Effect (95% CI)**	**P**		**n**	**Effect (95% CI)**	**P**
Implant failure	2	RR: 7.30 (2.79, 19.08)	<0.001		1	RR: 6.96 (2.51, 19.28)	<0.001		1	RR: 6.96 (2.51, 19.28)	<0.001
Mechanical complications	3	RR: 0.91 (0.51, 1.64)	0.76		-	-	-		Same as original		
Cumulative MBL (follow-up: 1 year)	3	MD: 0.08 (0.01, 0.14)	0.02		1	MD: 0.10 (-0.06, 0.26)	0.21		1	MD: 0.07 (-0.01, 0.15)	0.08

CI, confidence interval; MBL, marginal bone loss; MD, mean difference; n, number of studies; RR, relative risk

Appendix S7. Additional information about this review, including deviations from protocol.

Deviations from protocol

- The number needed to treat was planned to be calculated to clinically translate statistically significant relative risk, but no statistically significant relative risks were ultimately found.
- Possible sources of heterogeneity were planned a priori in the protocol to be sought through mixed-effects subgroup analyses and random-effects meta-regression for meta-analyses of at least five studies. This could ultimately not be assessed, as less than 5 studies were included in any meta-analysis.
- Reporting biases were planned to be assessed for meta-analyses of at least 10 studies using contour-enhanced funnel plots and with the Egger's weighted regression test. This could ultimately not be assessed, as less than 10 studies were included in any meta-analysis.
- The robustness of the results was planned to also be checked a priori with sensitivity analyses based on the inclusion/exclusion of non-randomized studies. However, no randomised trials were ultimately found, and this sensitivity analysis could not be performed.